Juvenile Lobster Data, Nursery Habitat Data, & Pre-recruit Modeling for the Florida Keys

Mark Butler & Tom Dolan

Department of Biological Sciences
Old Dominion University
Norfolk, VA

“Algal-phase” or “Early benthic juvenile” (EBJ)

- Majority of settlement habitat on bayside in hard-bottom habitat where red macroalgae is abundant
- Choice of settlement habitat driven by chemical cues & habitat structure
- Settlement of postlarvae & survival of postlarvae and EBJ in macroalgae is higher than in seagrass
- Postlarvae & EBJ sensitive (i.e., low survival) to environmental degradation (e.g., siltation, salinity and temperature change, disease)
- EBJ solitary in macroalgae; emerge from algae ~ 2 - 3 mos after settling at ~ 20 mm CL.

“Postalgal-phase” or “Crevice-dwelling” juvenile

- Size: ~ 25 – 55mm CL
- Majority on bayside in hard-bottom habitat
- Choice of shelter depends on lobster size, shelter type, & presence of other lobsters; on average, 60% found in groups

Surveys of Juvenile *P. argus* in south Florida

- Diver-based surveys
- Only comparable survey data sets available are those since 1988?
- Majority are those by ODU, FWC, & FSU research group; additional data sets: Eggleston, Lipcius, others?
- Focus on "post-algal" crevice-dwelling juveniles
  - 25 – 55 mm CL (range collected: 6 – 95 mm CL)
  - algal-dwelling early benthic juveniles (EBJ) difficult to census
- Most data based on CPUE timed surveys, but also a more limited number of area-based & mark-recapture data sets.
- Nursery habitat data also collected at each site in surveys by ODU/FWC/FSU

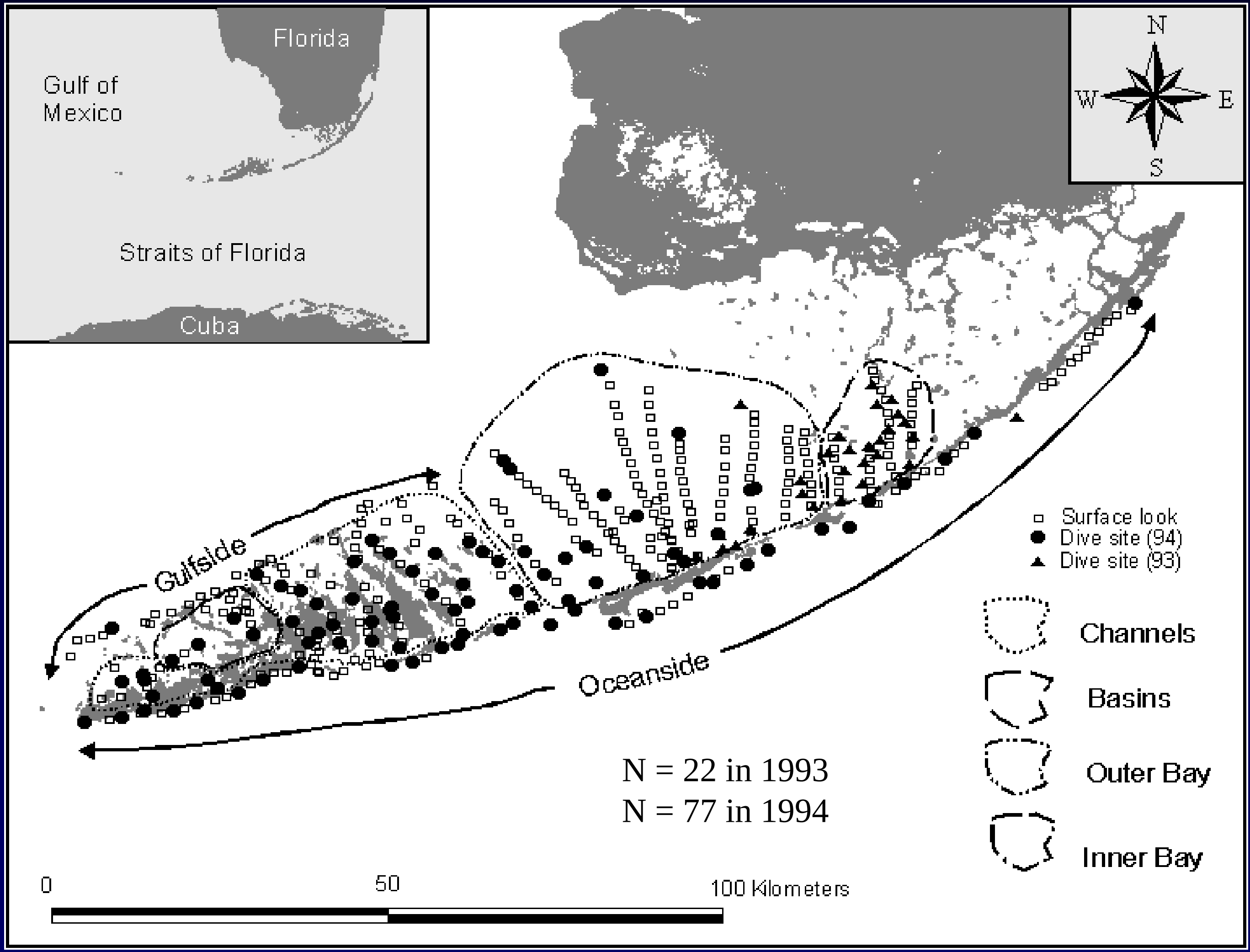
Summary Characteristics of Juvenile *P. argus* Survey Data by ODU/FWC/FSU

Project Code	**Years**	**# Natural Sites / # Sites with Art. Shelter**	**Sample Frequency**	**Geographic Coverage***	Types of Lobster Data Collected
ODB	1988-89	3 / 6	~ 1/mo.	M	CPUE, M-R
EARTH	1988-89	22 /0	1/yr	M	CPUE
JEP	1990-93	9/ 18	~ 1/mo.	M	Area & M-R
FIELD	1992	20 / 0	once	U & M	CPUE
PBLOOM	1993	22/ 0	once	U, M & L	CPUE
RAMS	1993-96	18 / 0	once	U & M	Area, CPUE, M-R
MAVRO	1994	77/ 0	once	U, M & L	CPUE
ACID	1995-97	6 / 6	~ 4 mos.	M	Area, CPUE, M-R
SCHR	1995-97	16	once	M	Area, CPUE, M-R
SGHB	1997	6	~ 6 mos.	M	CPUE
RCRT	1998-02	12 / 12	~ 4 mos.	U, M & L	CPUE
BEHR	1998-02	4 / 8	~ 6 mos.	M & L	Area, CPUE, M-R
CARA1	2002	135 / 0	once	U, M & L	CPUE
CARA2-3	2003-04	32 / 0	1/yr	U, M & L	CPUE
BISC	1992, 1993 & 2002	9	1/yr	B	CPUE

* Geographic codes: U = Upper Keys, M = Middle Keys, L = Lower Keys, B = Biscayne Bay

PBLOOM (1993) & MAVRO (1994) Projects

Juvenile *P. argus* Surveys - ODU/FWC/FSU



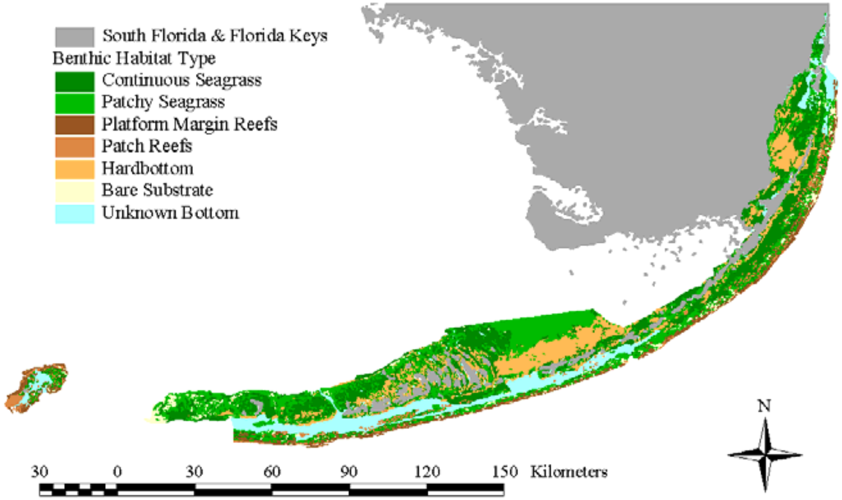
CARA1 Survey Design (2001): ODU/FWC

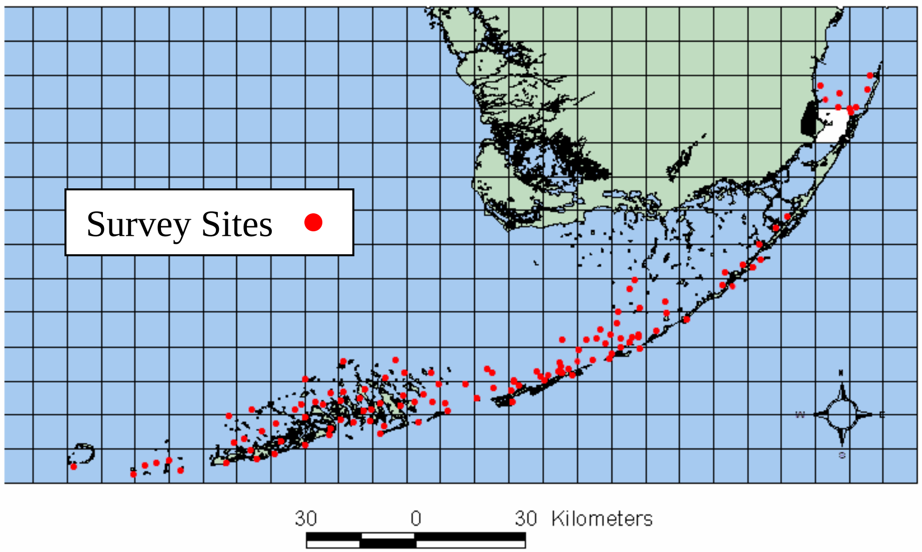
- **hard-bottom < 4m from Biscayne Bay to Marquesas Keys; N = 135 sites**
- **double-stratified, proportional sampling design**

  - top stratum: seven biogeographic hard-bottom regions from prior surveys

  - subordinate strata: various hard-bottom habitats in GIS benthic database

  - central bay region: offshore & nearshore (< 1km) representation





Timed Diver Surveys of Juvenile Lobster

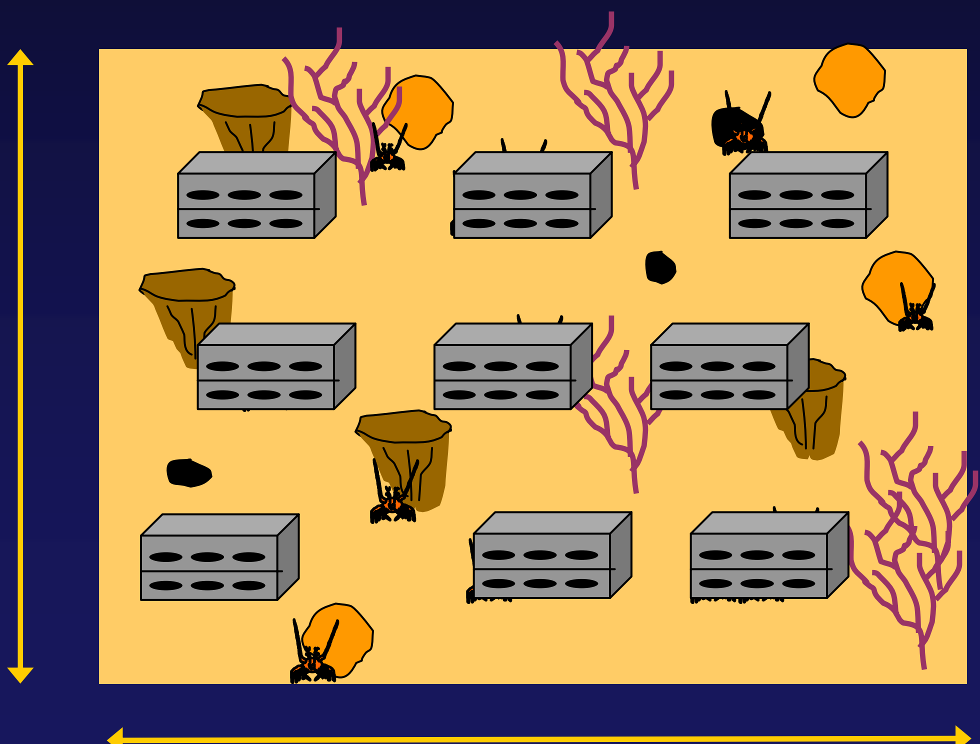
- CPUE: 2 Divers 30 min. each / site
- Search crevice shelters & collect all lobsters encountered
- Data recorded on boat; lobsters released

Area-Based Surveys

- Density: 1-2 Divers search all crevice shelters within defined area
- Often coupled with mark-recapture studies
- Often experimental studies: e.g. habitat manipulation

Natural

25m or 50m



25m or 50m

Artificial Shelters

Artificial Crevice Shelters

- Scaled to appropriate size for juvenile lobsters
- Scattered, random distribution like natural shelters

Juvenile Lobster Individual Data Collected

In all ODU/FWC/FSU studies:

- Size (carapace length; nearest 0.1 mm)
- Sex
- Molt condition (pre-molt, post-most, intermolt)
- Injuries (new, old, antennae, legs, etc.)

In many ODU/FWC/FSU studies:

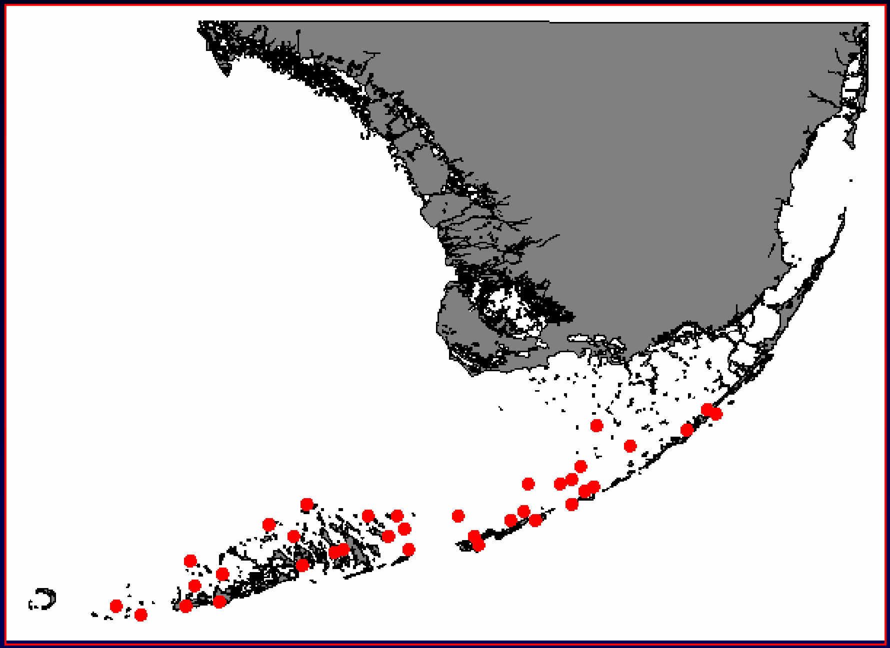
- Weight (to nearest 0.1g)
- Molt stage (AB, C, D_0, D_1, etc.)
- Nutritional condition (blood protein concentration)
- Disease (visual, histological, or PCR assessment)
- Shelter type from which they collected
- Other shelter inhabitants (lobster, crabs, etc.)

Other Data Collected During Juvenile Lobster Surveys

- Taken at all ODU/FWC/FSU lobster survey sites since 1988, but level of taxonomic detail varies by study
- Nursery habitat structure: potentially includes:
  - macroalgal % cover (some cases algal volume, other vegetative cover)
  - density of large crevice structures (sponges, octocorals, corals, holes, etc.)
  - large crevice shelter size structure
  - density of misc. sessile organisms (small corals, sponges, anemones, etc.)
- Fish & macroinvertebrate density (large crabs, gastropods, echinoderms, etc.)

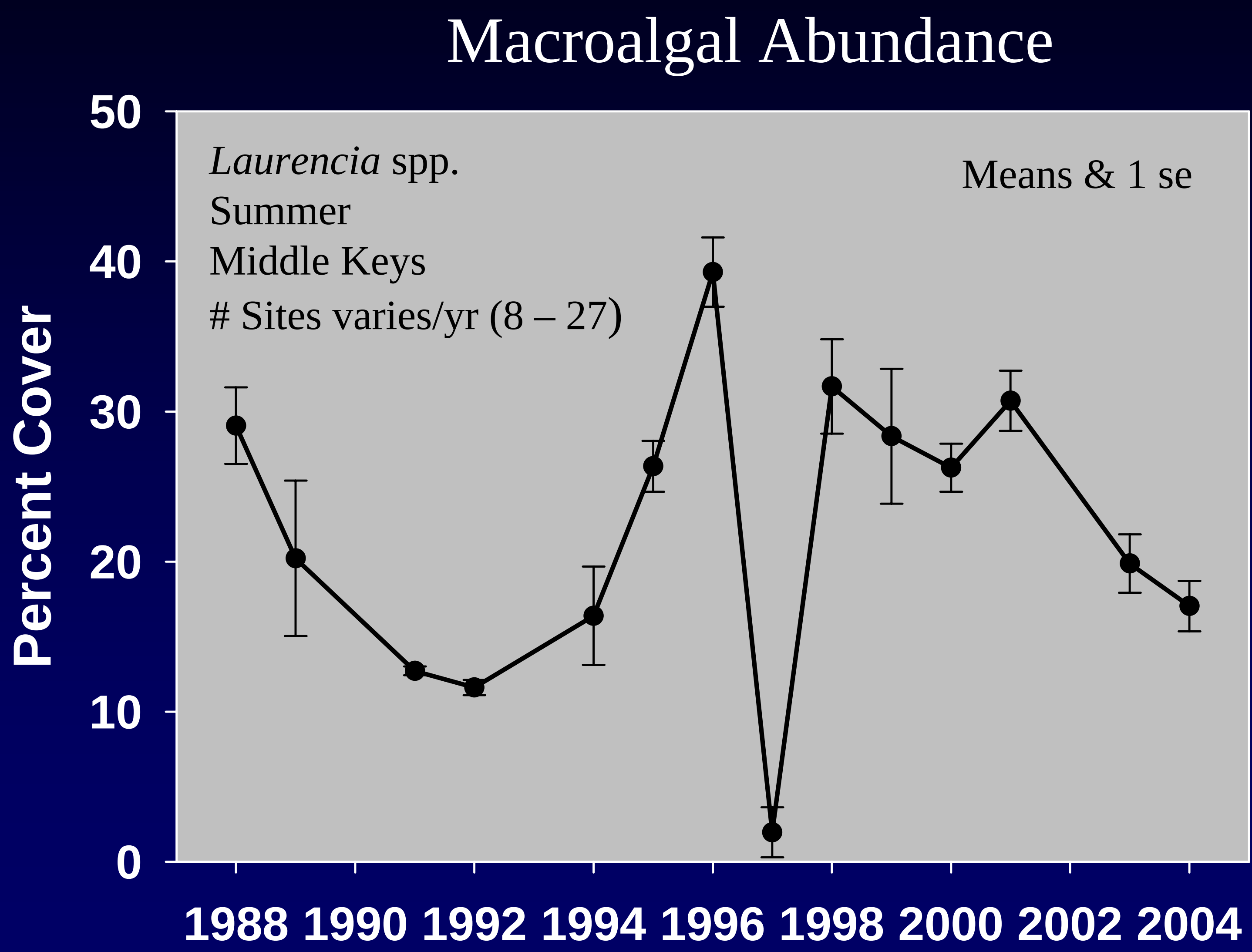
Current ODU/FWC Juvenile Lobster & Hard-bottom "Monitoring"

- 35 fixed sites: Key Largo to The Lakes (subset of 135 CARA1 sites)



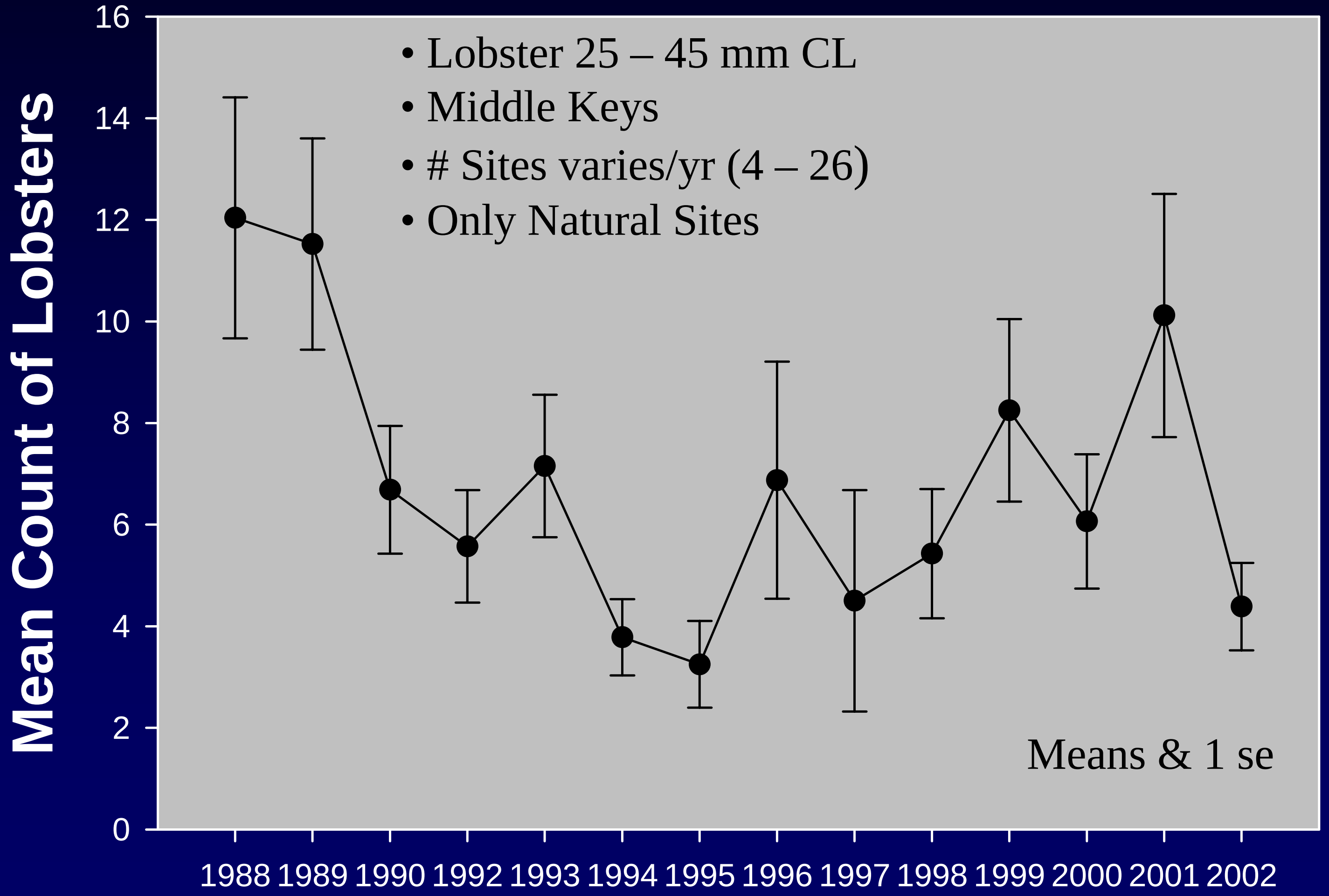
- CPUE Lobster surveys (size, sex, injuries, disease): (2) 30 min surveys
- Macroalgal & vegetative % cover: (4) 25 m fixed line transects
- Density large sessile taxa (30 species): (4) 2 x 25m fixed belt transects
- Density small sessile taxa (18 species): (16) 1 x 1m fixed quadrats
- Density of motile macroinverts (14 species): (4) 2 x 25m fixed belt transects
- Size structure of large sessile taxa

A Look at Some General Trends



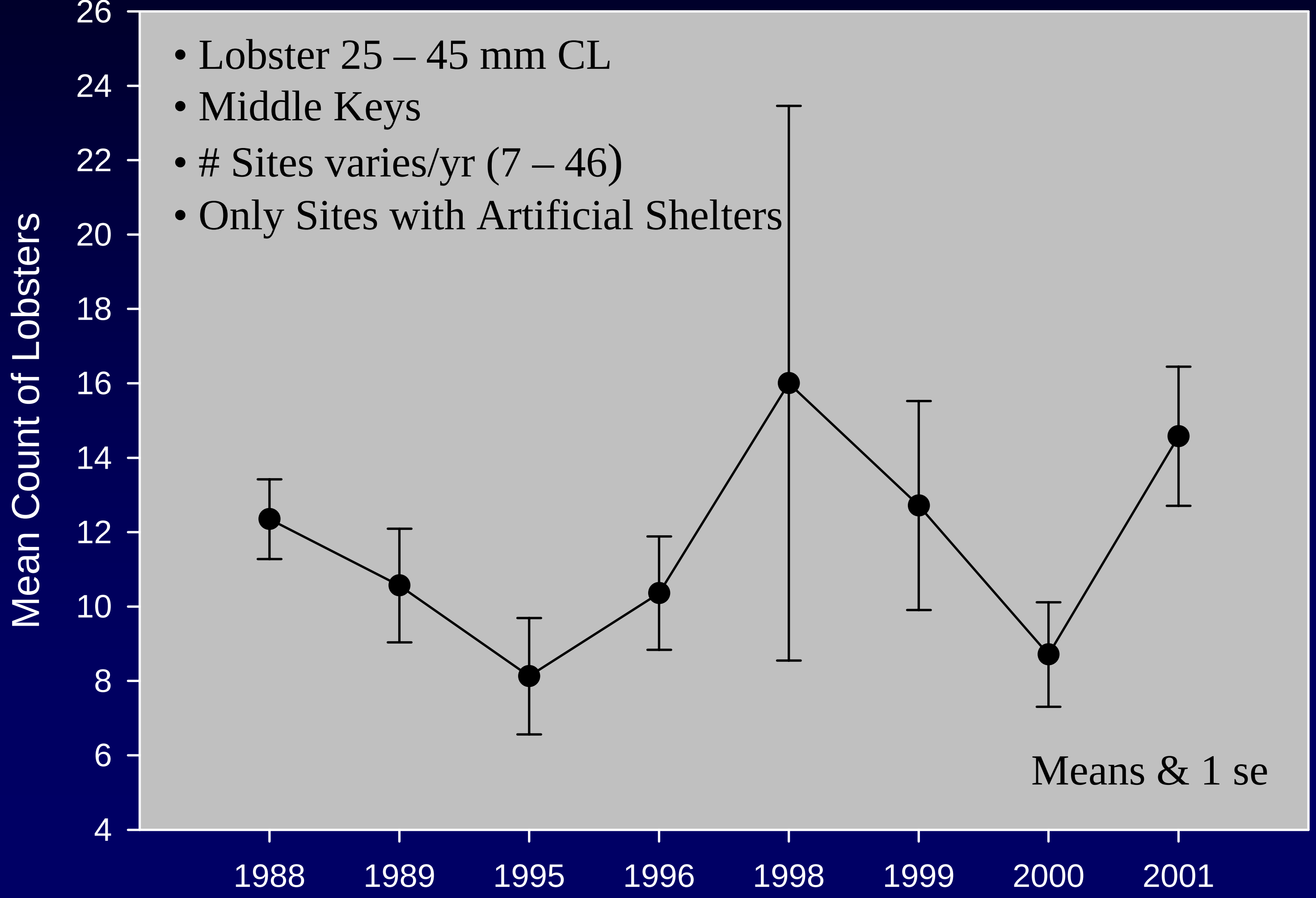
A Look at Some General Trends

Juvenile Lobster Abundance: Natural Sites



A Look at Some General Trends

Juvenile Lobster Abundance: Sites with Artificial Shelters



Why measure nursery habitat?

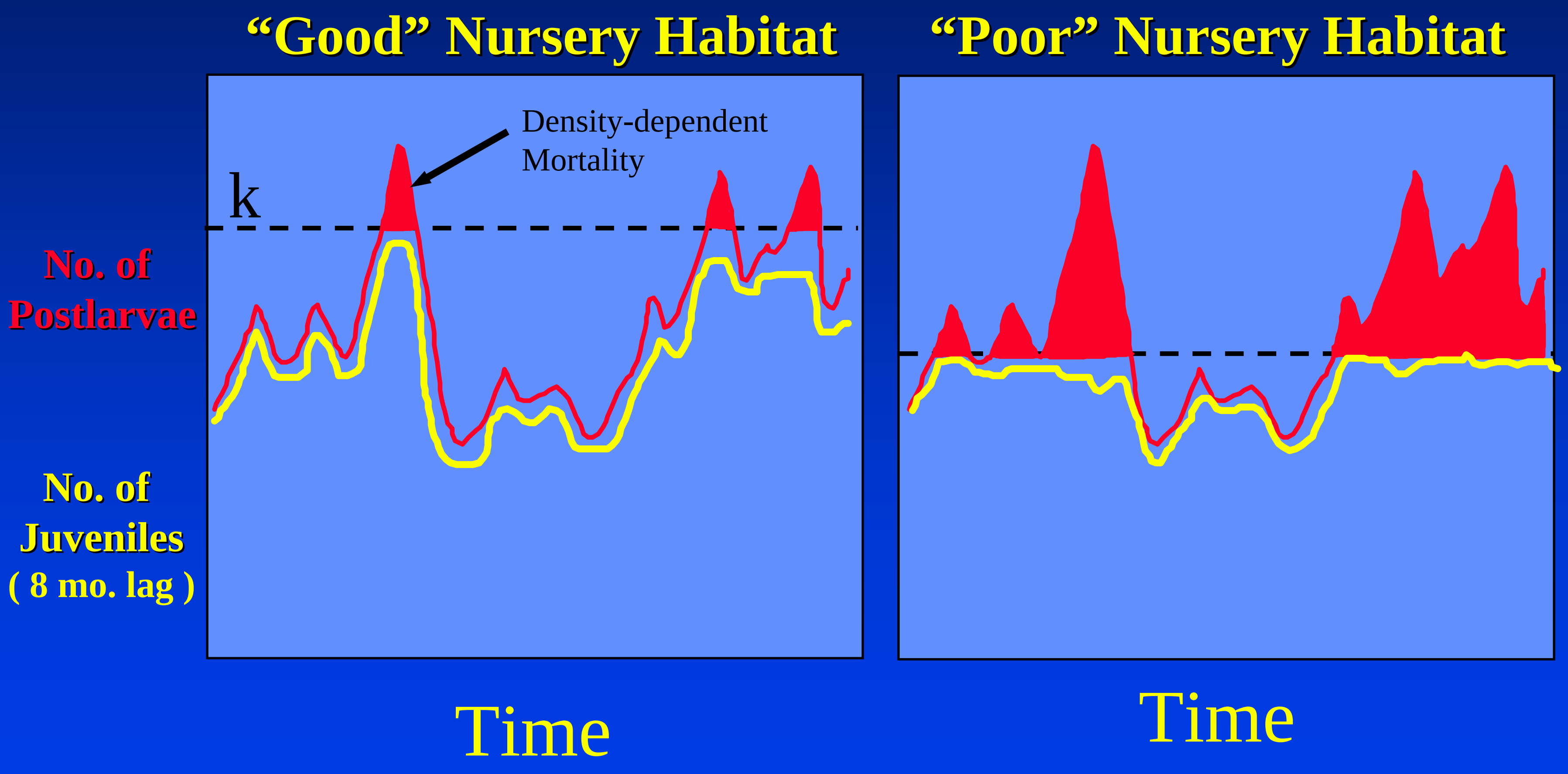
- Nursery habitat for lobsters (macroalgae, sponges, seagrass, etc.) is more dynamic than adult habitat & changes in response to:
  - plankton blooms (e.g., sponges)
  - salinity & temperature (e.g., sponges, octocorals)
  - water quality (e.g., seagrass, macroalgae)
  - fisheries (e.g., sponge fishery)

- Evidence for lobsters in Florida that the availability of nursery habitat can limit local recruitment, but this varies among sites

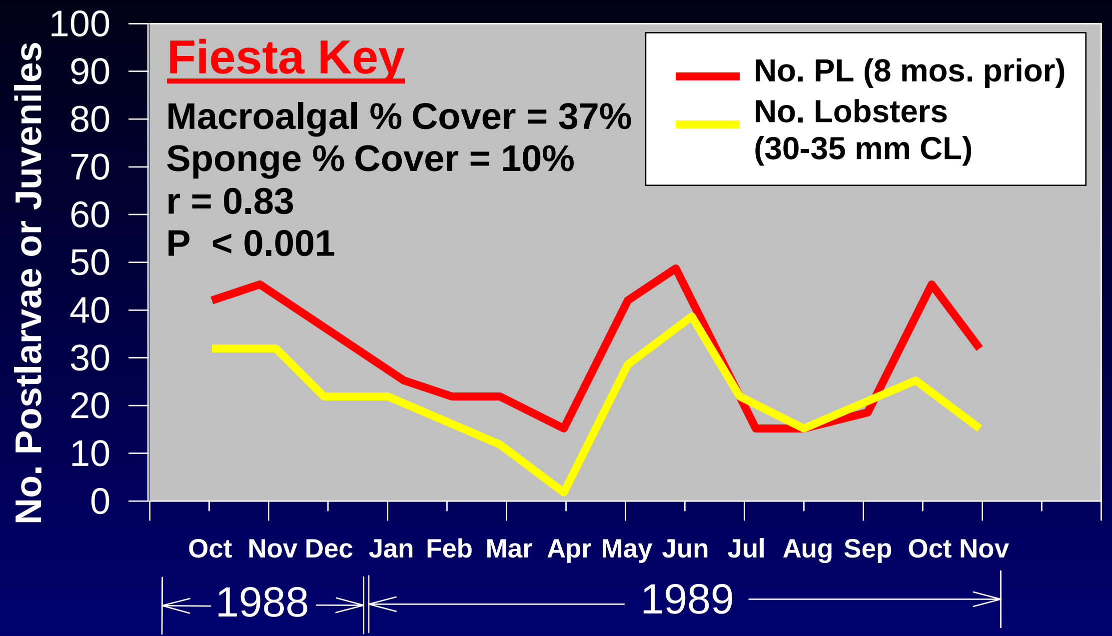
Experimental Studies of Recruitment Limitation of *Panulirus argus* in Florida

- Marx & Herrnkind (1985) J. Crust. Biol. 5: 650-657
- Herrnkind & Butler (1986) Mar. Ecol. Prog. Ser. 34: 23-38
- Herrnkind, Butler & Tankersley (1988). Fish. Bull. 86: 331-338
- Butler & Herrnkind (1992) Proc. Gulf Carib. Fish. Inst. 41: 508-515
- Herrnkind & Butler (1994) Crustaceana 67: 46-64
- Field & Butler (1994) Crustaceana 67: 26-44
- Forcucci, Butler & Hunt (1994) Bull. Mar. Sci. 54: 805-818
- Childress & Herrnkind (1994) Bull. Mar. Sci. 54: 819-827
- Mintz et al. (1994) Mar. Ecol. Prog. Ser. 112: 255-266
- Butler et al. (1995) Mar. Ecol. Prog. Ser. 129: 119-125
- Butler & Herrnkind (1997) Can. J. Fish. Aquat. Sci. 54: 452-463
- Acosta & Butler (1997) Mar. Freshwat. Res. 48: 721-727
- Acosta & Butler (1997) Limnol. Oceanogr.
- Herrnkind et al. (1997) Mar. Freshwat. Res. 48: 759-769
- Herrnkind & Butler (1997) Fisheries 22: 24-27
- Butler et al. (in press) Ecol. Appl. . . . . ETC.

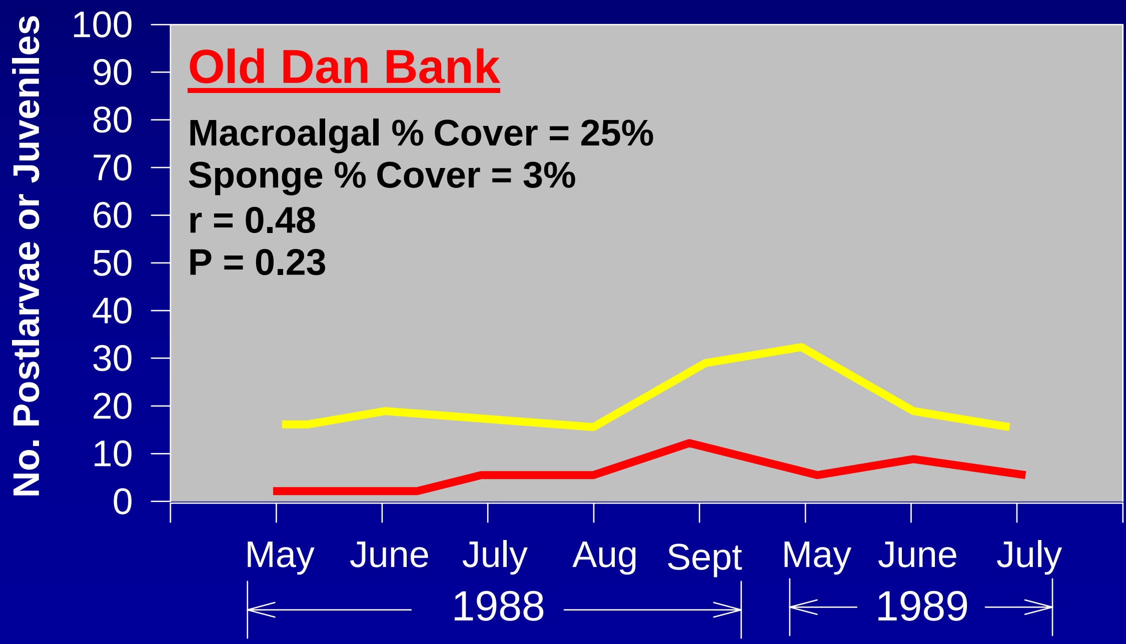
A Conceptualization of Local Recruitment Limitation



"Excellent" Nursery Habitat



"Average" Nursery Habitat



How does regional variation in postlarval supply and nursery habitat structure influence lobster recruitment in the Florida Keys?

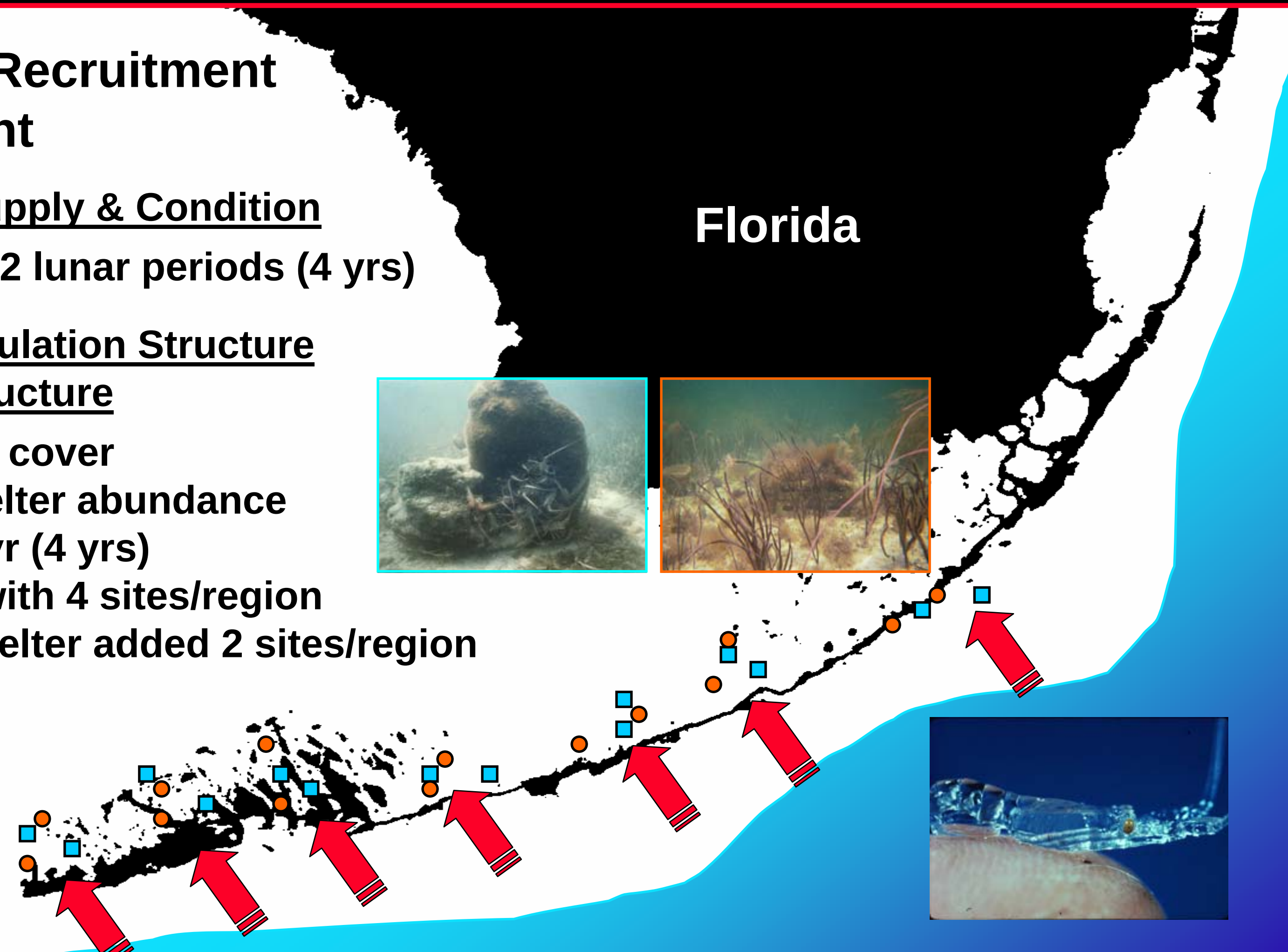
Regional Recruitment Experiment

<u>Postlarval Supply & Condition</u>

- 7 regions; 52 lunar periods (4 yrs)

<u>Juvenile Population Structure & Habitat Structure</u>

- macroalgal cover
- crevice shelter abundance
- 3 surveys/yr (4 yrs)
- 7 regions with 4 sites/region
- artificial shelter added 2 sites/region



Recruitment Limitation Field Study

Multiple Regression: No. Recruits per Site = Algae + Shelter + Postlarvae

Natural Sites n = 14 sites

	Algae	**Shelter**	Postlarvae
Correlation (r)	0.27	**0.67**	0.20
P-value	0.18	**< 0.005**	0.25

R = 0.76 $R^2 = 0.58$ $F = 4.53$, $P = 0.03$; df = 3,10

Habitat Enhanced Sites n = 14 sites

	Algae	Shelter	**Postlarvae**
Correlation (r)	0.07	0.13	**0.66**
P-value	0.40	0.33	**< 0.005**

R = 0.71 $R^2 = 0.51$ $F = 3.41$, $P = 0.05$; df = 3,10

Effect of Habitat Enhancement Varies Spatially!

Field Study Preliminary Results:
2-Factor ANOVAs Testing Effects in Each Region

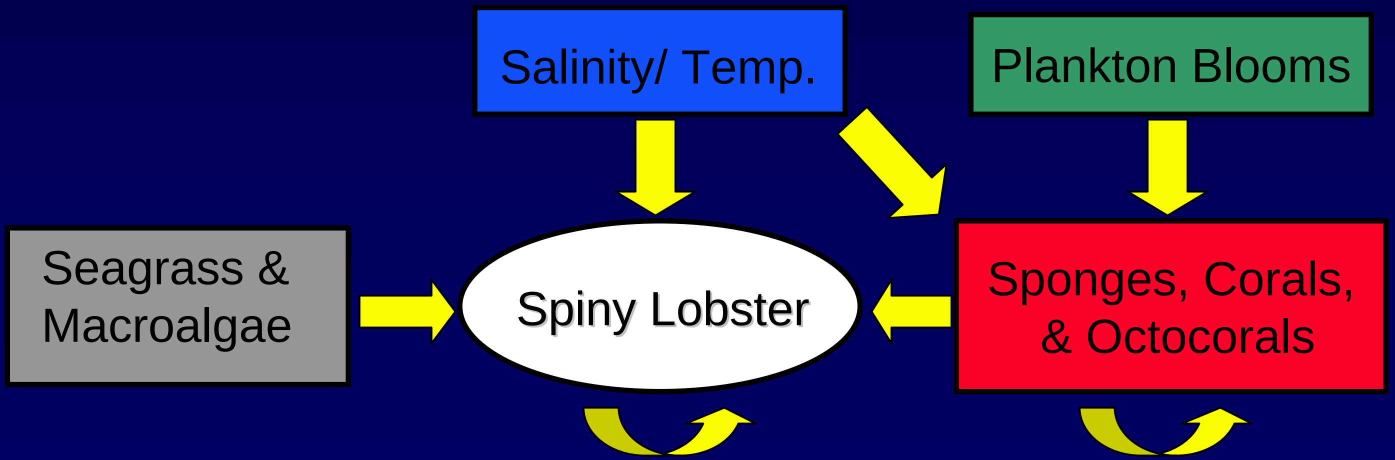
Region	P-values from ANOVA			Recruitment Limited By?
	Treatment	Season	Trt x Season	
Big Munson	0.976	0.586	0.524	Postlarvae
Boca Chica	**< 0.001**	0.047	0.368	Habitat
Cudjoe	0.197	0.944	0.129	Postlarvae
Little Duck	**< 0.001**	0.017	0.482	Habitat
Tom's Harbor	0.356	0.777	0.813	Postlarvae
Old Dan Bank	**0.017**	0.514	0.842	Habitat
Tavernier Creek	0.532	0.824	0.138	Postlarvae

Summarize Recruitment Limitation Issue

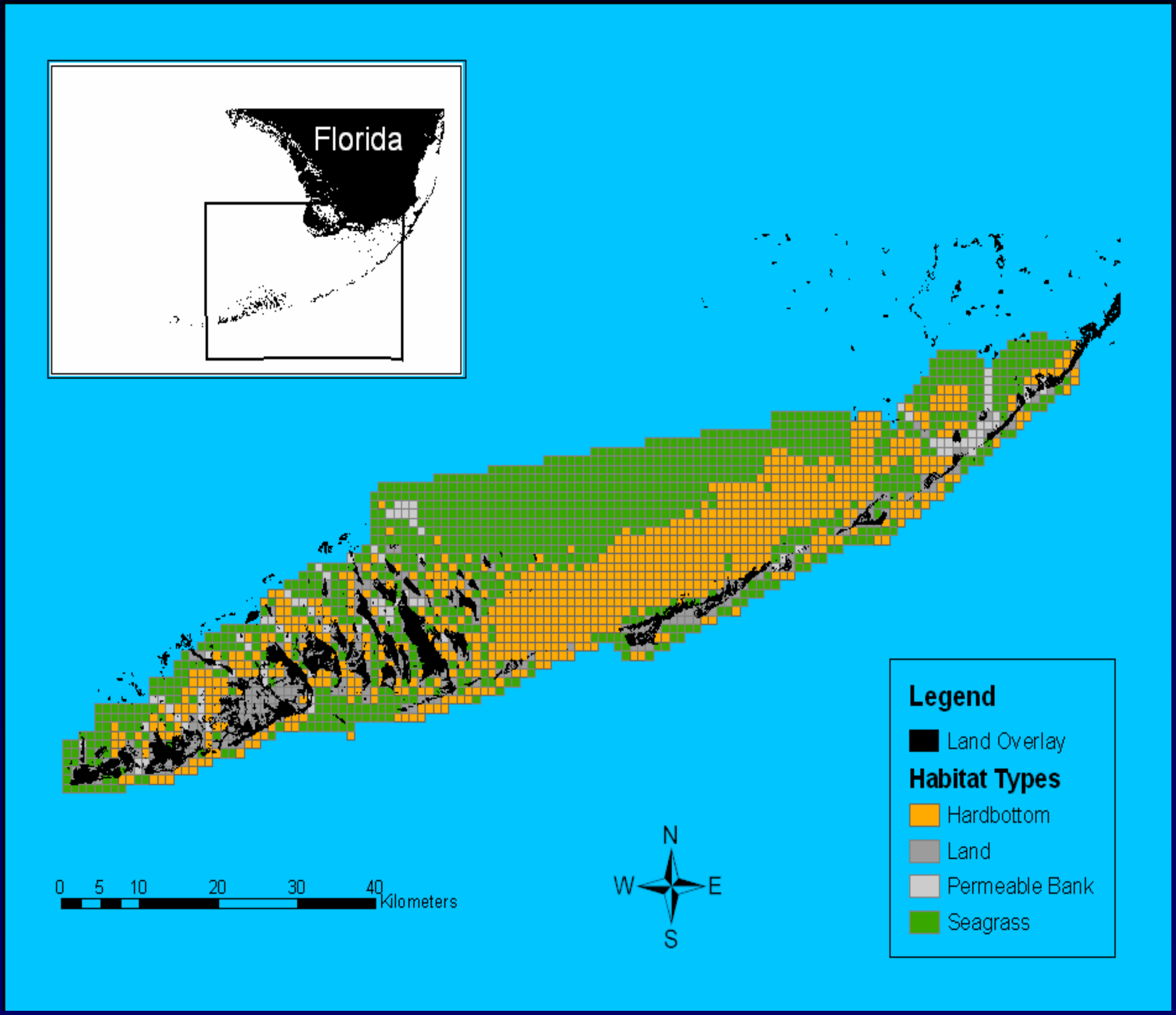
- Processes that limit recruitment vary locally on scales ~ 100s m to km.
- Thus, settlement may limit recruitment at one site whereas at nearby site it is habitat structure that controls strength of recruitment – a spatial mosaic of ecological process.
- Recruitment Indices:
  - \# postlarvae (from collectors)
  - \# post-algal juveniles (from surveys)
  - other factors to consider: nursery habitat change, disease?
- One approach that can potentially integrate these factors to provide a pre-recruit index & recognizes local dependency: use of spatially-explicit, individual-based modeling

A spatially-explicit, individual-based model of juvenile lobster recruitment in the Florida Keys

- <u>Format:</u>
  - integration of a spatially-explicit environmental landscape with individual-based population dynamics of juvenile lobsters (postlarvae to 50 mm CL)
- <u>Multi-Trophic Level Coverage:</u>



Spatial Structure of Individual-Based Spiny Lobster Recruitment Model

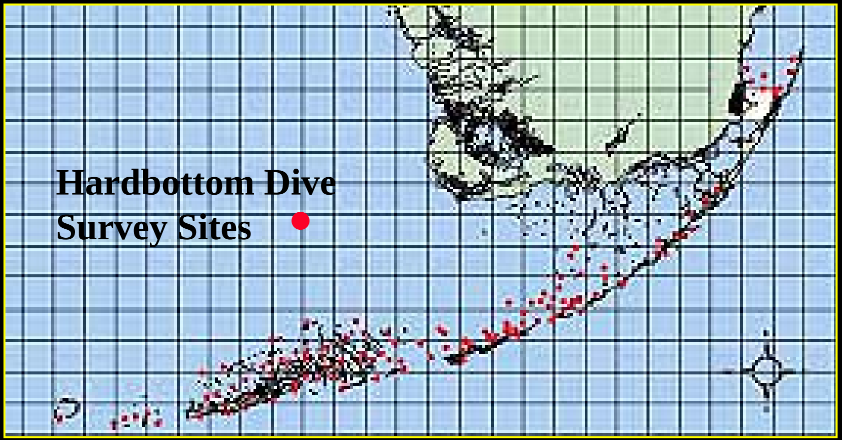


Cell-specific shelter structure

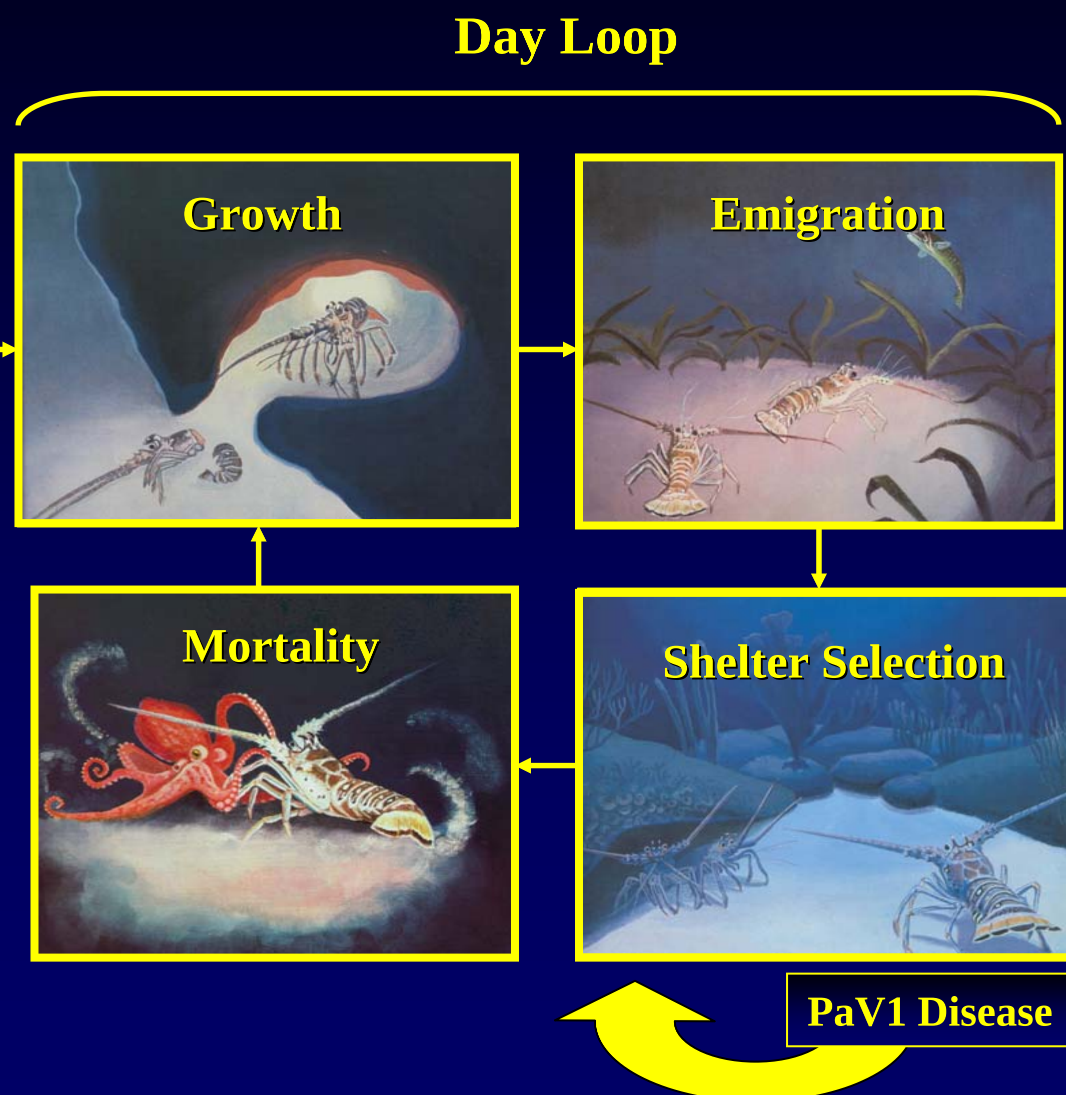
Hardbottom Cell

For each hard-bottom habitat cell we, determine a shelter-specific carrying capacity fnc:

- **Number shelters**
- **Size shelters**
- **Mean number of lobsters/shelter type**



Individual-based Population Dynamics



- empirically-based probability functions
- daily time step for each individual in model for specified number of yrs

(e.g. ~ 10 million individuals in a 10 year simulation)

Strengths & Weaknesses of Juvenile Lobster Data

Strengths

- 16 year time-series
- consistency of methods
- habitat data too
- Middle Keys data in all yrs
  - large fraction of nursery
  - most dynamic region
- good estimate of:
  - number of lobster >25 mm CL

Weaknesses

- spatial inconsistency over time
- CPUE bias at high lobster density due to time-to-catch?
- habitat data detail varies
- poor estimate of:
  - number < 25 mm CL
  - sizes of lobster >45 mm CL

Is it lunch-time yet?

A Look at Some General Trends

Juvenile Lobster Abundance: Natural & Artificial Sites